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The power of catastrophic optical mirror degradation in InGaAs/AlGaAs/GaAs QW laser diodes

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Abstract. We report on the fabrication and characteristics of conventional QW SCH InGaAs/AlGaAs broad area laser diodes. The detailed investigation of 100 μm striped contact laser diodes produced by MBE technique shows the strong dependence of a differential quantum efficiency ($T_1 = 280-420$ K) on temperature. This factor gives the strong influence on the output power. The power of catastrophical optical mirror degradation of InGaAs/AlGaAs laser diodes may reach practically the same (20 MW/cm^2) data as for Al-free laser diodes. The output power of 6.3 W (CW, 280 K) in InGaAs/AlGaAs QW SCH 100 μm stripe is achieved.

Introduction

The main factor limiting the optical output power of semiconductor lasers is catastrophic mirror degradation (COMD). It caused by overheating of the active region at the mirrors. Last years many papers devoted to the continuous wave very high powers from diode lasers have been published [1–2]. The achievement of record high CW powers stay possible due to the new "broadened waveguide" (BW) construction of laser diodes and application of Al-free semiconductor compounds for laser heterostructures. The increase of waveguide thickness in BW construction decreases the light power density and prevents the mirror overheating. The overheating process is not clear in detail until this time. Some authors believe the overheating due to light absorption in "dead layer" that appears in active region near the facets, some of them connect the overheating with the surface recombination. Botez showed [3] that maximum optical power is limited by surface recombination rate of active region material. In any case the overheating temperature is strongly connected first of all with active region materials [4]. Thus the above mentioned explanations of COMD do not limit the material for the laser heterostructures by Al-free compounds only. We have found that investigation of maximum optical power in SCH QW AlGaAs/GaAs laser diodes with InGaAs quantum well active region is of interest.

1. Experiment

We grew the SCH QW InGaAs/AlGaAs/GaAs laser heterostucture by the TsNa-4 molecular beam epitaxy system on oriented n^+-type GaAs (001) substrate. The schematics band diagram of the heterostructure is shown in Fig. 1.

The structure contains 0.8 μm thick $Al_{0.6}Ga_{0.4}As$ emitters. The 85 Å $In_{0.18}Ga_{0.82}As$ active region is confined by 0.5 μm thick waveguide layers of variable gap AlAs/GaAs superlattice with linearly varying band gap, similarly to the equivalent graded layer $Al_{0.43}Ga_{0.57}As/Al_{0.29}Ga_{0.71}As$. For our investigation 100 μm SiO_2 stripe lasers was fabricated.

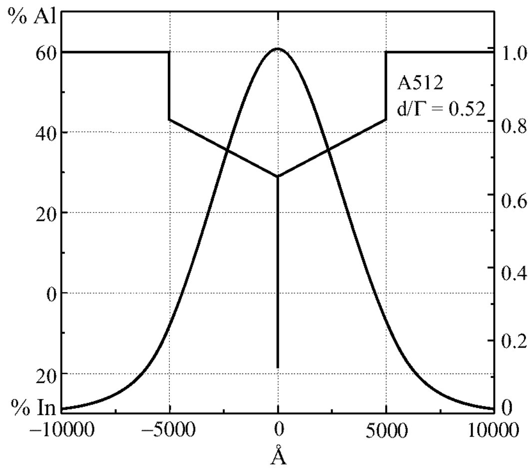

Fig. 1. The schematics band diagram of the heterostructure and calculated optical field distribution.

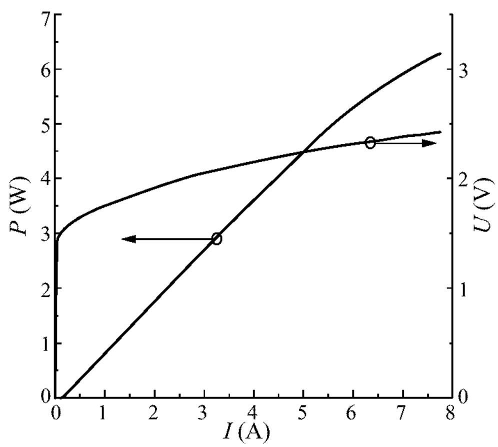

Fig. 2. Power vs current an voltage vs current characteristics of investigated laser.

In Fig. 2 are presented output power vs. current and voltage vs current characteristics recorded at CW condition at temperature 280 K. One can see in power vs current characteristic that maximum power reach 6.3 W at 7.75 A. As far as we know output power 6.3 W is one of the best results for non Al-free lasers. It is difficult to compare different laser because there are too many kind of laser construction. To compare our result with different lasers output power we use an optical power density:

$$P_{\mathrm{COMD}} = \frac{P_{\max}}{(d/\Gamma)W[(1-R)/(1+R)]}, \tag{1}$$

where $P_{\max}$ is maximum optical power, W is stripe width, R is front facet reflectivity, d is active region thickness and Γ is optical confinement factor.

Calculated electrical field distribution is shown in Fig. 1 d/Γ ratio obtained from our calculations is 0.52. Under these condition we get P_{COMD} above 20 MW/cm^2. This value is near the best results for Al-free lasers. So we can conclude that Al-free active region in non Al-free waveguide in SCH QW semiconductor lasers demonstrate good P_{COMD} value.

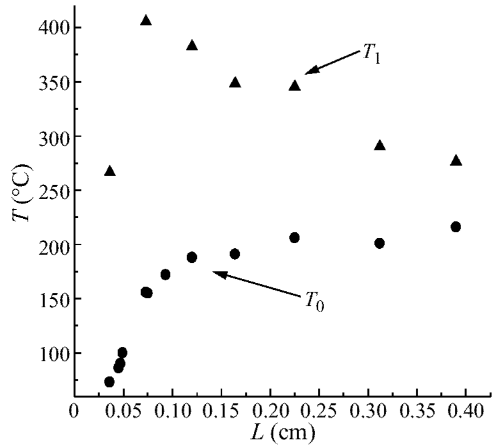

Fig. 3. The dependencies of characteristic temperature T_0 and T_1 vs the cavity length.

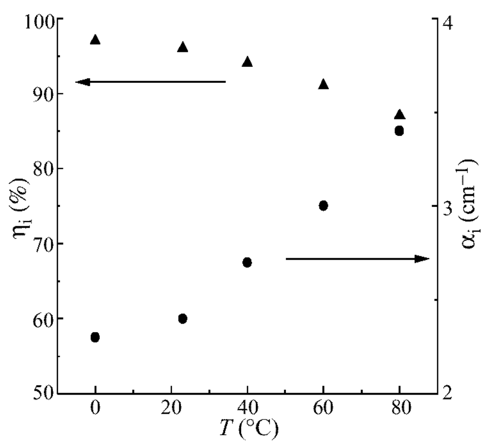

Fig. 4. Internal losses α_i and internal quantum efficiency η_i vs temperature.

At the current higher as 5 A the power–current dependence receive the sublinear character. To find the reason of such behavior we measured the power-current characteristics for laser diodes with different cavity length in a temperature range of $-10\ldots+80$°C. We estimated the characteristic temperature T_0 and T_1 that describe accordingly the temperature dependencies of threshold current and differential quantum efficiency. The dependencies of characteristic temperature T_0 and T_1 vs the cavity length of the laser diode are given in Fig. 3.

The value of $T_0 = 180-200$ K are typical for InGaAs/AlGaAs and Al-free laser diodes in all range of cavity length. At the same time it is important to note the value of parameter $T_1 = 270-280$°C for cavity length more as 3 mm is too low. The reason of such low value of T_1 parameter may be the temperature dependence of internal losses α_i or the temperature dependence of internal quantum efficiency η_i. We extract these dependencies from experimental data (Fig. 4). The main contribution of the temperature dependence of differential quantum efficiency gives the dependence of internal losses on the temperature. So, the reduction of internal optical losses in investigated InGaAs/AlGaAs laser diodes is

mandatory for the achievement of the maximal optical power.

2. Conclusion

By this paper we show that the output power of catastrophically optical mirrors damage of traditional InGaAs/AlGaAs QW SCH laser diodes may have practically the same value as for Al-free laser diodes. The maximum output power of investigated broad area laser diodes of 6.3 W (CW, 280 K) is achieved. This value is controlled mainly by the very high temperature sensitivity of differential quantum efficiency of InGaAs/GaAs laser diodes.

Acknowledgements

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